# The inverse analysis of strength parameter in a loess landslide

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## Content



## 1 The stability analysis of loess slope at present

Research status

- Qualitative analysis method
  - Natural (causes) history analysis method
  - Engineering analogy method
  - Graphical method
- Quantitative analysis method
  - The limit equilibrium analysis
  - Finite element method
- Uncertain analysis method
  - Reliability analysis method
  - Fuzzy comprehensive evaluation method
  - Neural network evaluation method

## The importance of the inverse analysis

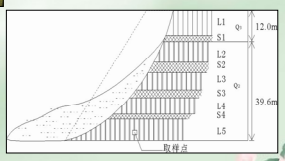
- The complexity of geological conditions
- The deviation of calculation model
- The uncertainty of strength parameter
- ……

→ The inverse analysis

## 2 The engineering geological conditions of Jijiayuan cutting loess slope

The photo of Jijiayuan slope

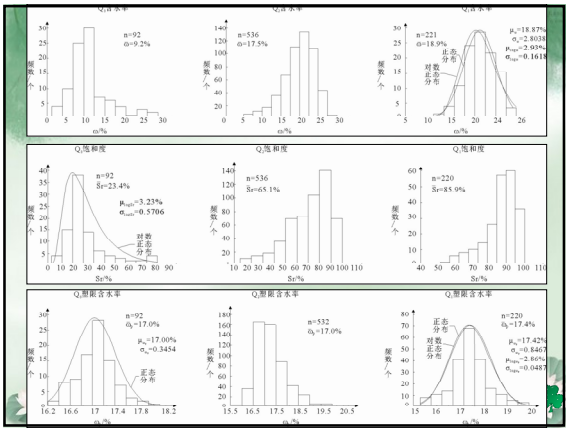
Jijiayuan slope is a cutting loess slope located beside the G209 national highway in Shanxi Province, In the process of operation, it become unstable.

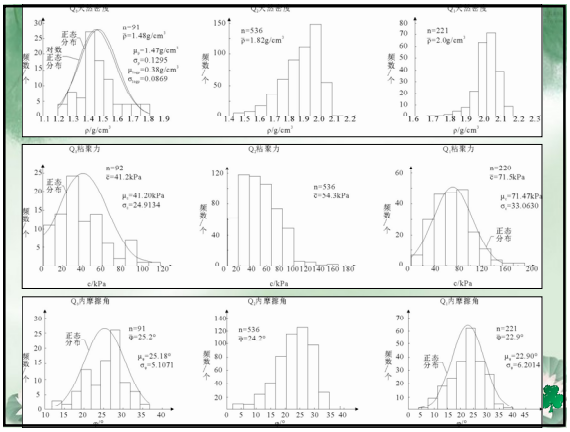



The profile of the slope

## Statistical process

Count the physical and mechanic indexes of $Q_3$、$Q_2$ and $Q_1$ loess, draw into histogram, then conduct the hypothesis testing of normal distribution and lognormal distribution 0.05 level of confidence



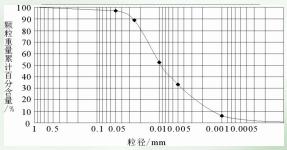


## the statistical of the physical properties

| 参数 | $Q_3$ | $Q_2$ | $Q_1$ |
|---|---|---|---|
| ω | 9.2% | 17.5% | 18.9% |
| $S_r$ | 23.4% | 65.1% | 85.9% |
| $ω_p$ | 17.0% | 17.0% | 17.4% |
| ρ | 1.48g/cm³ | 1.82 g/cm³ | 2.0 g/cm³ |
| c | 41.2kPa | 54.3 kPa | 71.5 kPa |
| φ | 25.2° | 24.2° | 22.9° |

## 3 The physical and mechanical index test of L5 loess

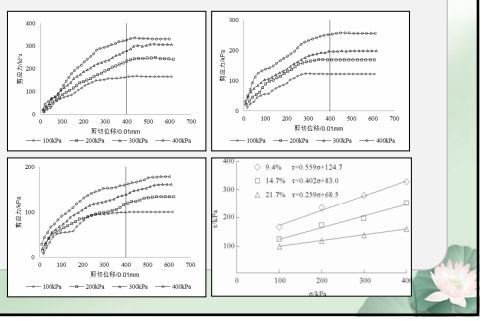
### Particle size gradation curve



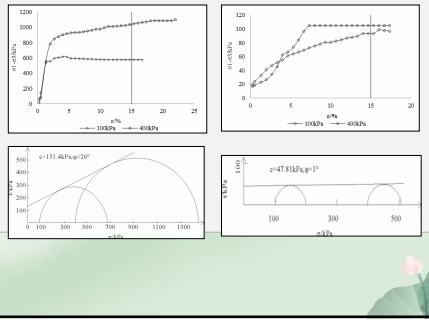
### Basic physical index

| $ρ_s$ g/cm³ | Y g/cm³ | ρ g/cm³ | e | ω /% | $ω_p$/% | $ω_l$/% | $I_P$/% | $I_L$/% |
|---|---|---|---|---|---|---|---|---|
| 2.71 | 1.85 | 1.61 | 0.69 | 14.8 | 19.7 | 30.1 | 10.4 | -0.5 |

## direct shear test



## Triaxial test

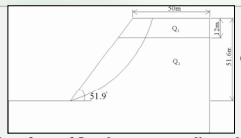


## test results

| Soil samples state | Test method | ω /% | c/kPa | φ /(° ) |
|---|---|---|---|---|
| Undisturbed soil | Direct fast shear test | 9.4 | 124.7 | 29.2 |
| | | 14.7 | 83.0 | 21.9 |
| | | 21.7 | 68.5 | 14.5 |
| | UU Triaxial test | 13.3 | 131.4 | 26 |
| | | 28.8 | 47.8 | 1.0 |

## 4 The Inverse Analysis of Strength Parameter

### The process of inverse analysis

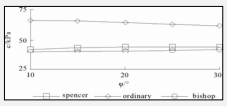



Control Fs=1

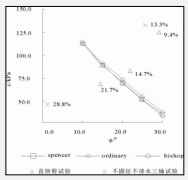
- The value of c, φ of $Q_2$ select corresponding value of tab.1, Setting the value of φ of $Q_3$ between 10° ~30° ,selecting 5 piants φ =10， φ=15， φ=20， φ=25， φ=30，and start the inverse analysis of c;
- The value of c, φ of $Q_3$ select corresponding value of tab.1, Setting the value of φ of $Q_2$ between 10° ~30° ,selecting 5 piants φ=10， φ=15， φ=20， φ=25， φ=30，and start the inverse analysis of c;

## Inversion result

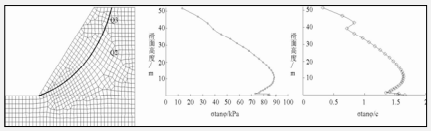
$Q_3$ c、φ inversion curve




$Q_2$ c、φ inversion curve




## Numerical simulation




contribution of c and φ values to the stability of slopes under different height of slide face

## 5 Conclusions

If the normal stress of sliding surface increased，the value of φ will control the stability of slopes ； If the normal stress is small，the value of c will control the stability of slopes. In the example of Jijiayuan slope, when the depth of sliding surface is about 20m, the value of c、 φ have equivalent affect on stability of slopes. So when we calculate stability of slope in practical project , for the lower slope, we should consider mainly the value of c , for the higher slope, we should consider mainly about the value of φ.

Through comparing the inversion results and test results of soil samples, we found that plastic limit moisture content is the start moisture content of loess landslide , its corresponding strength to startup strength. In practical project, we can select strength parameters obtained though the direct and quick shear under the conditions that the soil sample's moisture content is plastic limit moisture content for evaluation the slope stability.

## Thanks for your attention!